Macroeconomic Effects of Financial Shocks*

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Abstract

In this paper we document the cyclical properties of U.S. firms' financial flows. Debt payouts are countercyclical and equity payouts are procyclical. We develop a model with explicit roles for debt and equity financing and we study its business cycle implications. Standard productivity shocks can only partially explain the observed variations in real variables and financial flows. We show that financial shocks that affect firms' capacity to borrow can bring the model much closer to the data. The recent events in the financial sector show up clearly in our model as a tightening of firms' financing conditions in 2008 and as a cause for a downturn in GDP growth and other macroeconomic variables. The model also suggests that the downturns in 1990-91 and 2001 were strongly influenced by changes in the credit conditions.

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1 Introduction

Recent economic events starting with the subprime crisis in the summer of 2007 suggest that the financial sector plays an important role in the transmission and source of business cycle fluctuations. While there is a long tradition in macroeconomics to model financial frictions, most of the literature has not tried to match simultaneously real aggregate variables as well as financial flows such as debt and equity. Moreover, financial shocks—that is perturbations that affects directly the financial sector—do not play a central role in the literature. Most of the focus has been directed at understanding the amplification mechanism generated by the financial sector rather than looking at the financial sector as one of the sources of business cycle fluctuations. In this paper we attempt to make some progress along these lines.

We start by documenting the cyclical properties of firms' equity and debt flows at an aggregate level. We then build a business cycle model with explicit roles for firms' debt and equity financing. We show that the model driven solely by measured productivity shocks fails to capture the key dynamic features of the U.S. business cycle as well as the behavior of equity and debt flows. Augmenting the model with credit or financial shocks that directly affect firms' ability to borrow brings the model much closer to the data—not only for financial flows but also for some of the real business cycle quantities, especially labor. When we further characterize the credit shocks, we find that the model implies a worsening of firms' ability to borrow in 2008, which is in line with the standard interpretation of economic events since the summer of 2007. Moreover, the model implies that economic downturns in 1990-91 and 2001 were strongly influenced by changes in the credit conditions.

In our model firms finance investment with equity and debt. Debt contracts are not fully enforceable and the ability to borrow is limited by a no-default constraint which depends on the expected lifetime profitability of the firm. As lifetime profitability varies with the business cycle, so does a firm's ability to borrow. In this regard our model is related to Kiyotaki & Moore (1997), Bernanke, Gertler & Gilchrist (1999), and Mendoza & Smith (2005), in the sense that asset prices movements affect the ability to borrow. Our model, however, differs in two important dimension. First, we allow firms to issue new equity in addition to reinvesting profits.[1] Second,

[1] There are other studies that allow for equity issuance over the business cycle. See, for example, Choe, Masulis & Nanda (1993), Covas and den Haan (2005), Leary and Roberts (2005), and Hennessy & Levy (2005). The main focus of these studies is on the financial

we consider shocks that affect directly the financial sector of the economy. Therefore, the financial sector can act as a source of the business cycle in addition to changing the propagation of shocks that originate in other sectors of the economy. In this respect our paper is related to Benk, Gillman & Kejak (2005,2008) who also consider shocks affecting the financial sector. However, the nature of the financial shock and the structure of the model considered in these papers are completely different from our.

The paper is structured as follows. In Section 2 we consider some empirical evidence on real and financial cycles in the US economy. Section 3 presents the model and characterizes some of its analytical properties. Model calibration and quantitative findings are presented in Sections 4.

2 Real and financial cycles in the U.S.

This section presents the main empirical observations that motivate the paper. It describes the properties of real and financial business cycles.

We start by reporting the business cycle properties of firms' aggregate financial flows. To our knowledge, these properties have not been previously documented and explored in the macro literature. Figure 1 plots the net payments to equity holders and the net debt repurchases in the nonfinancial business sector (corporate and noncorporate). Financial data is from the Flow of Funds Accounts of the Federal Reserve Board. Equity payout is defined as dividends and share repurchases minus equity issues of nonfinancial corporate businesses, minus net proprietor's investment in noncorporate businesses. This captures the net payments to business owners (shareholders of corporations and noncorporate business owners). Debt is defined as 'Credit Market Instruments' which include only liabilities that are directly related to credit markets instruments. It does not include, for instance, tax liabilities. Debt repurchases are simply the reduction in outstanding debt (or increase if negative). Both variables are expressed as a fraction of nonfarm business GDP. See Appendix A for a more detailed description.

Two patterns are visible in the figure, very strongly so for the second half of the period considered. First, equity payouts are negatively correlated with debt repurchases. This suggests that there is some substitutability between equity and debt financing. Second, while equity payouts tend to increase in

behavior of firms, not in the quantitative impact of financial frictions for the propagation of aggregate shocks to the macro economy.

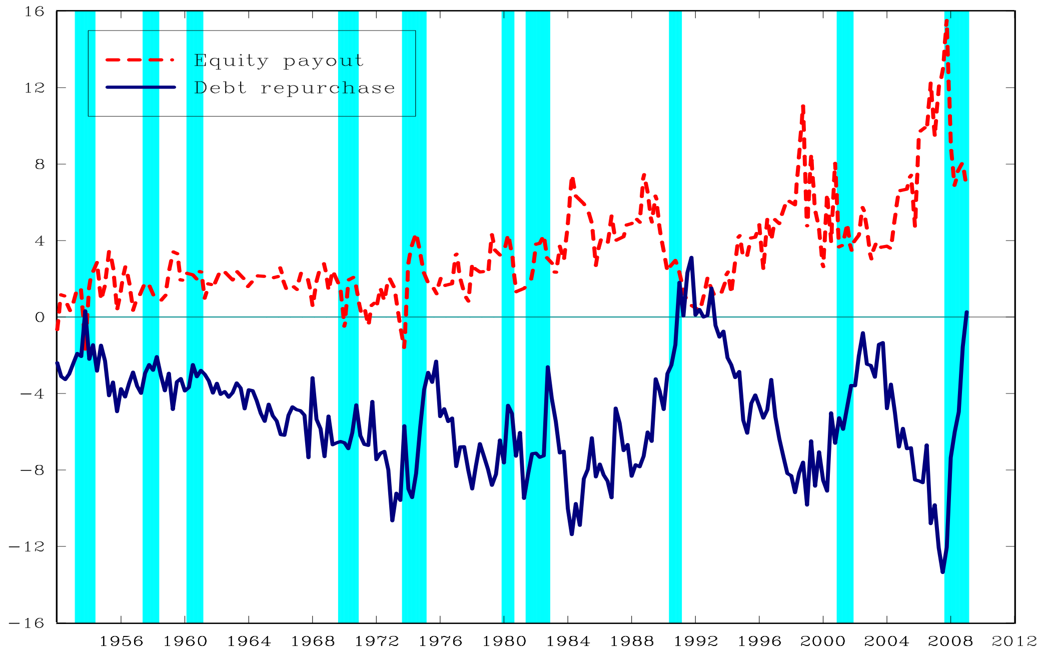

Figure 1: Financial flows in the nonfinancial business sector (corporate and noncorporate): 1952.1-2009.1. Source: Flow of Funds, Federal reserve Board.

booms, debt repurchases increase during or around recessions. This suggests that recessions lead firms to restructure their financial positions by cutting debt and reducing the payments made to shareholders.

The properties of real and financial cycles are further characterized in Table 1. The table reports the standard deviations and correlations with GDP for equity payouts and debt repurchases in the nonfinancial corporate sector and in the nonfinancial corporate and noncorporate sectors combined. Statistics for a number of key business cycle variables are also presented. Equity payouts and debt repurchases are normalized by the value added produced in the sector. For these two variables we do not take logs because some observations are negative. All variables are detrended with a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999)).

We focus on the period after 1984 for two related reasons. First, it has been widely documented in relation with the so called Great Moderation that 1984 corresponds to a break in the volatility in many business cycle variables until recently. Second, as documented in Jermann and Quadrini (2008), this

Table 1: Business cycles properties of macroeconomic and financial variables, 1984:1-2008:4.

	Std(Variable)	$\frac{\text{Std(Variable)}}{\text{Std(GDP)}}$	Corr(Variable,GDP)
Macroeconomic variables			
GDP	0.85		
Consumption (N.D.& S.)	0.50	0.59	0.83
Investment	3.98	4.68	0.85
Hours	1.18	1.39	0.81
TFP	0.50	0.59	0.41
Financial variables			
EquPay/GDP (Corporate)	1.27	1.49	0.44
DebtRep/GDP (Corporate)	1.42	1.67	-0.65
EquPay/GDP (Corp.&Noncorp.)	1.08	1.27	0.50
DebtRep/GDP (Corp.&Noncorp.)	1.34	1.58	-0.77

Notes: Financial data is from the Flow of Funds Accounts of the Federal Reserve Board. *Equity payout* in the corporate sector is net dividends minus net issue of corporate equity (net of share repurchases). *Equity payout* in the nonfarm business sector is equity payout in the corporate sector minus proprietor's net investment. *Debt repurchase* is the negative of the change in credit market liabilities. Both variables are divided by their sectorial GDP. The macroeconomic variables have been logged. All variables are detrended with a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999). See Appendix A for more details.

time period also saw major changes in U.S. financial markets compared to the previous period. In particular, spurred by regulatory changes, share repurchases had become more common, and this seemed to have had a major impact on firms' payout policies and financial flexibility. Therefore, by concentrating on the period after 1984 we do not have to address the causes of the structural break that arose in the early 1980s.

The correlations of equity payouts and debt repurchases with output confirm the properties we highlighted in Figure 1. Equity payouts are procyclical and debt repurchases are countercyclical, and these properties hold for the nonfinancial corporate sector alone, as well as for the total nonfinancial business sector. The business cycle properties of the real variables are well known, and we will get back to them when comparing our model to the data.

3 Model

We start describing the environment in which an individual firm operates as this is where our model diverges from a more standard business cycle model. We then present the household sector and define the general equilibrium.

3.1 Financial and investment decisions of firms

There is a continuum of firms, in the $[0, 1]$ interval, with a gross revenue function $F(z_t, k_t, l_t) = z_t k_t^{\theta} l_t^{1-\theta}$. The variable z_t is the stochastic level of productivity, k_t is the input of capital depreciating at rate δ and l_t is the input of labor.

Firms use equity and debt. Debt is preferred to equity (pecking order) because of its tax advantage as, for example, in Hennessy and Whited (2005). Given r_t the interest rate, the effective gross rate for the firm is $R_t = 1 + r_t(1-\tau)$, where τ determines the tax benefit.

The ability to borrow is bounded by the limited enforceability of debt contracts as firms can default on their obligations. Let $\overline{V}_t(k_{t+1}, b_{t+1})$ be the equity value of the firm at the end of the period, after paying dividends. This is defined as the expected discounted value of equity payout starting from the next period, that is,

$$\overline{V}_t(k_{t+1}, b_{t+1}) = E_t \sum_{j=1}^{\infty} m_{t+j} d_{t+j},$$

where m_{t+j} is the relevant stochastic discount factor, derived later, and d_{t+j} are the net payments to the shareholders (equity payout). We made explicit that the equity value at the end of the period depends on the individual state variables capital and debt. The subscript t captures the dependence on aggregate states. The firm's value is typically decreasing in the end-of-period debt because, everything else equal, debt reduces the future payments that can be made to the shareholders.

Default arises after the realization of revenues. In case of default, the firm has the ability to retain the revenues $F(z_t, k_t, l_t)$, as these are liquid funds that can be easily diverted, and renegotiates the debt. In case of renegotiation the lender can sell the firm but can recover only a fraction $\xi_t < 1$ of the equity value $\overline{V}_t$. The variable ξ_t is stochastic and it is the same for all firms. It captures the degree of market liquidity along the lines of Kiyotaki and Moore (2008).

Because of the loss of value in liquidating the firm, both parties have an interest in renegotiating the debt. The net surplus from reaching an agrement is $(1-\xi_t)\overline{V}_t$. Without loss of generality (see Appendix B) we assume that the firm has the whole bargaining power, and therefore, the value retained in the renegotiation stage is $(1-\xi_t)\overline{V}_t$. Thus, the total value from defaulting is $F(z_t,k_t,l_t)+(1-\xi_t)\overline{V}_t$, that is, the retained revenues plus the renegotiation value. Enforcement requires that the value of the firm, $\overline{V}_t$, is at least as big as the value of defaulting, that is, $\overline{V}_t \geq F(z_t,k_t,l_t)+(1-\xi_t)\overline{V}_t$. Rearranging terms, the enforcement constraint can be rewritten as:

$$\xi_t \overline{V}_t(k_{t+1}, b_{t+1}) \geq F(z_t, k_t, l_t). \tag{1}$$

The detailed description of the intra-period transactions and timing of the renegotiation game that leads to this constraint is provided in Appendix B.

The stochastic variable ξ_t plays a crucial rule in determining the borrowing capacity of the firm and we refer to it as aggregate "credit shock". To see more clearly how ξ_t affects the financial and production decisions of the firm, we rewrite the enforcement constraint in a slightly modified fashion. First, let's define $V_t(k_t, b_t) = d_t + \overline{V}_t(k_{t+1}, b_{t+1})$ the equity value of the firm at the beginning of the period, before paying dividends. At the beginning of the period the states of the firms are the capital and the debt chosen in the previous period. Then the enforcement constraint can be rewritten as follows:

$$\xi_t \Big[V_t(k_t, b_t) - d_t \Big] \geq F(z_t, k_t, l_t).$$

At the beginning of the period k_t and b_t are given. Therefore, the only variables that can be changed to balance the enforcement constraint are the input of labor, l_t, and the equity payout, d_t. Therefore, if we start from a pre-shock state in which the enforcement constraint is binding and the firm wants to keep the production plan unchanged, a negative credit shock (lower ξ_t) requires a reduction in equity payout d_t. In other words, the firm is forced to increase equities, and therefore, to reduce the debt. However, if the firm cannot reduce d_t, it has to cut employment.[2]

To formalize the rigidities affecting the substitution between debt and equity, we assume that the firm's payout is subject to a quadratic cost:

$$\varphi(d_t) = d_t + \kappa \cdot (d_t - \bar{d})^2$$

[2]Notice that credit and productivity shocks are the same for all firms, that is, they are aggregate shocks. Hence, we can concentrate on the symmetric equilibrium where all firms are alike (representative firm).

where $\kappa \geq 0$ and $\bar{d}$ represents the long-run payout target (steady state).

The equity payout cost should not be interpreted necessarily as a pecuniary cost. It is a simple way of modeling the speed with which firms can change the source of funds when the financial conditions change. Of course, the possible pecuniary costs associated with share repurchases and equity issuance can also be incorporated in the function $\varphi(.)$. The convexity assumption would then be consistent with the work of Hansen & Torregrosa (1992) and Altinkilic & Hansen (2000), showing that underwriting fees display increasing marginal cost in the size of the offering.

Another way of thinking about the adjustment cost is that it captures the preferences of managers for dividend smoothing. Lintner (1956) showed first that managers are concerned about smoothing dividends over time, a fact further confirmed by subsequent studies. This could derive from agency problems associated with the issuance or repurchase of shares as emphasized by several studies in finance. The explicit modeling of these agency conflicts, however, is beyond the scope of this paper.[3]

The parameter κ is key for determining the impact of financial frictions. When $\kappa = 0$, the economy is almost equivalent to a frictionless economy. In this case, debt adjustments triggered by the credit shocks can be quickly accommodated through changes in firm equity. When $\kappa > 0$, the substitution between debt and equity becomes costly and firms readjust the sources of funds slowly. This implies that, in the short-run, shocks have an important impact on the production decision of firms.

Firm's problem: We now write the problem of the firm recursively. The individual states are the capital stock, k, and the debt, b. The aggregate states, which we will make precise later, are denoted by $\mathbf{s}$.

The firm chooses the input of labor, l, the equity payout, d, the new capital, k', and the new debt, b'. The optimization problem is:

$$V(\mathbf{s}; k, b) \;=\; \max_{d,l,k',b'} \left\{ d + Em'V(\mathbf{s}'; k', b') \right\} \tag{2}$$

subject to:

[3] As an alternative to the adjustment cost on equity payouts, we could use a quadratic cost on the change of debt, which would lead to similar properties. Therefore, our model can be interpreted more broadly as capturing the rigidities in the adjustment of all sources of funds, not only equity.

$$(1-\delta)k + F(z,k,l) - wl + \frac{b'}{R} = b + \varphi(d) + k'$$

$$\xi E m' V(\mathbf{s}'; k', b') \geq F(z,k,l)$$

The problem is subject to the budget and the enforcement constraints. The function $V(\mathbf{s}; k, b)$ is the cum-dividend (fundamental) market value of the firm and m' is the stochastic discount factor. The variables w and R are, respectively, the wage rate and the gross interest rate. The stochastic discount factor, the wage and interest rate are determined in the general equilibrium and are taken as given by an individual firm.

Denote by μ the Lagrange multiplier associated with the enforcement constraint. The first-order conditions are:

$$F_l(z,k,l) = w \cdot \Big(\frac{1}{1-\mu\varphi_d(d)}\Big), \tag{3}$$

$$(1+\xi\mu) E\, \tilde{m}' \Big[1 - \delta + (1-\mu'\varphi_d(d'))F_k(z',k',l')\Big] = 1, \tag{4}$$

$$(1+\xi\mu) R E\, \tilde{m}' = 1. \tag{5}$$

where $\tilde{m}' = m' \cdot \Big(\frac{\varphi_d(d)}{\varphi_d(d')}\Big)$ is the 'effective' stochastic discount factor. Subscripts denote derivatives. The detailed derivation is in Appendix C.

Especially important is the optimality condition for labor, equation (3), which is key for understanding the key results of this paper. This is the typical optimality condition in which the marginal productivity of labor is equalized to the marginal cost. The marginal cost is the wage rate augmented by a wedge that depends on the 'effective' tightness of the enforcement constraint, that is, $\mu\varphi_d(d)$. A tighter enforcement constraint increases, effectively, the cost of labor for the firm and reduces the demand of labor. Similarly, when the enforcement constraint becomes less tight, the effective cost of labor declines, increasing its demand. Therefore, the main transmission of credit shocks is through the demand of labor.

To get further insights, it will be convenient to consider the special case without any cost of equity payout, that is, $\kappa = 0$. Thus, $\varphi_d(d) = \varphi_d(d') = 1$, $\tilde{m}' = m'$ and condition (5) becomes $(1+\xi\mu)REm = 1$. Taking as given the aggregate prices R and Em', this condition implies that there is a negative relation between the credit shock, ξ, and the multiplier μ. In other words, lower liquidation values of the firm's equities make the enforcement constraint more binding. Then from condition (3) we see that a higher value of μ implies a lower demand of labor.

This mechanism is reinforced when $\kappa > 0$. In this case it will be costly to re-adjust the financial structure and the change in ξ induces a bigger change in μ. Of course, the change in the policies of the firms will also induce a change in the equilibrium prices, with some feedback on the individual policies. To characterize the price changes we have to close the model and derive the general equilibrium.

3.2 Households sector and general equilibrium

There is a continuum of homogeneous households maximizing the expected lifetime utility $E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t)$, where c_t is consumption, l_t is labor, and β is the discount factor. Households are the owners (shareholders) of firms. In addition to equity shares, they hold non-contingent bonds issued by firms.

The household's budget constraint is:

$$w_t l_t + b_t + s_t(d_t + q_t) = \frac{b_{t+1}}{1 + r_t} + s_{t+1} q_t + c_t + T_t$$

where w_t and r_t are the wage and interest rates, b_t is the one-period bond, s_t the equity shares, d_t the equity payout received from the ownership of shares, q_t is the market price of shares, and $T_t = B_{t+1}/[1 + r_t(1 - \tau)] - B_{t+1}/(1 + r_t)$ are lump-sum taxes financing the tax benefits received by firms on debt.

The first order conditions with respect to labor, l_t, next period bonds, b_{t+1}, and next period shares, s_{t+1}, are:

$$w_t U_c(c_t, l_t) + U_h(c_t, l_t) = 0 \tag{6}$$

$$U_c(c_t, l_t) - \beta(1 + r_t) E U_c(c_{t+1}, l_{t+1}) = 0 \tag{7}$$

$$U_c(c_t, l_t) q_t - \beta E(d_{t+1} + q_{t+1}) U_c(c_{t+1}, l_{t+1}) = 0. \tag{8}$$

The first two conditions are key to determine the supply of labor and the risk-free interest rate. The last condition determines the market price of shares. After re-arranging and using forward substitution, this price is:

$$q_t = E_t \sum_{j=1}^{\infty} \left(\frac{\beta^j \cdot U_c(c_{t+j}, l_{t+j})}{U_c(c_t, l_t)} \right) d_{t+j}.$$

Firms' optimization is consistent with households' optimization. Therefore, the stochastic discount factor is equal to $m_{t+j} = \beta^j U_c(c_{t+j}, l_{t+j})/U_c(c_t, l_t)$.

We can now provide the definition of a recursive general equilibrium. The set of aggregate states $\mathbf{s}$ are given by the current realization of productivity z, the current realization of the credit shock ξ, the aggregate capital K, and the aggregate bonds B. Therefore, $\mathbf{s} = (z, \xi, K, B)$.

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined as a set of functions for (i) households' policies $c(\mathbf{s}; b)$ and $l(\mathbf{s}; b)$; (ii) firms' policies $d(\mathbf{s}; k, b)$, $l(\mathbf{s}; k, b)$, $k(\mathbf{s}; k, b)$ and $b(\mathbf{s}; k, b)$; (iii) firms' value $V(\mathbf{s}; k, b)$; (iv) aggregate prices $w(\mathbf{s})$, $r(\mathbf{s})$ and $m(\mathbf{s}, \mathbf{s}')$; (v) law of motion for the aggregate states $\mathbf{s}' = H(\mathbf{s})$. Such that: (i) household's policies satisfy the optimality conditions (6)-(7); (ii) firms' policies are optimal and $V(\mathbf{s}; k, b)$ satisfies the Bellman's equation (2); (iii) the wage and interest rates are the equilibrium clearing prices in the labor and bond markets and $m(\mathbf{s}, \mathbf{s}') = \beta U_c(c_{t+1}, l_{t+1})/U_c(c_t, l_t)$; (iv) the law of motion $H(\mathbf{s})$ is consistent with individual decisions and the stochastic processes of z and ξ.*

3.3 Some characterization of the equilibrium

To illustrate some of the properties of the model, it will be convenient to look at two special cases in which the equilibrium can be characterized analytically. First, we show that for a deterministic steady state with constant z and ξ, the default constraint is always binding. Second, if $\tau = 0$ and $\kappa = 0$, changes in ξ (credit shocks) have no effect on the real sector of the economy.

Proposition 3.1 *The enforcement constraint binds in the steady state.*

In a deterministic steady state $m = 1/(1 + r)$ and $\varphi_d(d) = \varphi_d(d') = 1$. Therefore, the first order condition for debt, equation (5), simplifies to $(1+\bar{\xi}\mu)Rm = 1$, where $\bar{\xi}$ is the mean value of the credit shock. Substituting the above definition of m, we get $(1+\bar{\xi}\mu)R = 1+r$. Because $R = 1+r(1-\tau)$, we have that $\mu > 0$ if $\tau > 0$. Thus, as long as there is a tax benefit from issuing debt, the enforcement constraint is binding in a steady state.

With uncertainty, however, the constraint may not be binding at all times because firms may reduce their borrowing in anticipation of future shocks. However, the constraint is always binding if τ is sufficiently large and the shocks are sufficiently small. This will be the case in the quantitative exercises we conduct in this paper.

Let's consider now the stochastic economy concentrating on the special case in which $\tau = 0$ and $\kappa = 0$. We have the following proposition:

Proposition 3.2 *With $\tau = 0$ and $\kappa = 0$, changes in ξ have no effect on l and k'.*

When $\kappa = 0$ we have that $\varphi_d(d) = \varphi_d(d') = 1$ and $\tilde{m}' = m'$. Therefore, the first order condition (5) can be written as $(1 + \xi\mu)REm' = 1$. From the household's first order condition (7) we have that $(1+r)Em' = 1$. Combining these two conditions we get $(1 + \xi\mu)[1 + r(1 - \tau)] = 1 + r$. With $\tau = 0$ this condition implies $\xi\mu = 0$. Therefore, μ is always zero and, assuming that the aggregate prices do not change, the firm's choice of l and k' will not be affected by the change in ξ. What we have to show next is that the sequence of prices do remain constant if firms do not change l and k'. This becomes obvious once we recognize that changes in debt issuance and equity payout associated with fluctuations in ξ cancel out in the household's budget constraint. Therefore, the sequence of prices do not change in equilibrium and credit shocks are fully neutral for the real sector of the economy.

We have then established that, when $\tau = 0$ and $\kappa = 0$, business cycle movements are only driven by fluctuations in aggregate productivity z. The model becomes a standard RBC model. In fact, the key first order conditions become:

$$wU_c(c, l) + U_l(c, l) = 0,$$

$$F_l(z, k, l) = w,$$

$$E\left\{\frac{\beta U_c(c', l')}{U_c(c, l)}\right\}\Big[1 - \delta + F_k(z', k', l')\Big] = 1.$$

which are identical to the first order conditions obtained from the standard RBC model.

4 Quantitative analysis

We start the quantitative analysis by showing that the model with only productivity shocks has a limited ability to capture the financial and business cycle movements experienced by the U.S. economy since the mid 1980s. We then show that adding credit shocks not only improves the model's predictions for the financial flows, but also improves the ability to replicate the dynamics properties of key macroeconomic variables, especially working hours. The model can also capture the GDP downturn of 2008-09, as well as the downturns in the previous two recessions, 1990-91 and 2001. This suggests that tighter credit conditions have played an important role in all major recessions experienced by the U.S. economy since the mid 1980s.

4.1 Parametrization

There are two sets of parameters. The first set includes parameters that can be calibrated using steady state targets, some of which are typical in the business cycle literature. The second group includes parameters that cannot be calibrated using steady state targets. Therefore, for these parameters we use a different procedure.

4.1.1 Parameters set with steady state targets

The period in the model is a quarter. We set $\beta = 0.9825$, implying that the annual steady state return from holding shares is 7.32 percent. The utility function takes the form $U(c, l) = \ln(c) + \alpha \cdot \ln(1-l)$ where $\alpha = 1.9265$ is chosen to have steady state hours equal to 0.3. The Cobb-Douglas parameter in the production function is set to $\theta = 0.36$ and the depreciation to $\delta = 0.025$. The mean value of z is normalized to 1. These values are standard in the literature and they are based on the typical steady state targets. The quantitative properties of the model are not very sensitive to this first set of parameters.

The tax benefit is set to $\tau = 0.35$. This would be the benefit of debt over equity if the marginal tax rate is 35 percent. This parameter is important for the quantitative performance of the model because it determines whether the enforcement constraint is binding. As we will see, with this value of τ (and the remaining parametrization of the model), the enforcement constraint is almost always binding in all the simulations conducted in this paper.

The mean value of the credit variable, $\bar{\xi}$, is chosen to match the average leverage, that is, the ratio of debt, b, over the capital stock, k. We impose a steady state leverage of 0.4. This is about the average leverage obtained from the Flow of Funds for the Nonfinancial Business sector during the period 1984:1-2009:1.

4.1.2 Parameters that cannot be set with steady state targets

The parameters that cannot be set with steady state targets are those determining the stochastic properties of the shocks and the cost of equity payout (the parameter κ). Of course, in a steady state equilibrium, the stochastic properties of the shocks do not matter and the equity payout is always equal to the long-term target. Therefore, we have to use an alternative procedure.

Our approach to determine the parameters of the stochastic process for the shocks can be described as follows. We fist use the restrictions imposed by the model to construct the sequences of z_t and ξ_t for the period 1984:1-2009:1. Once we have constructed the shock series, we estimate a two dimensional autoregressive system.

For the productivity series we follow the standard procedure which is based on the Solow residuals. From the linearized version of the production function we have:

$$\hat{z}_t = \hat{y}_t - \theta\,\hat{k}_t - (1-\theta)\,\hat{l}_t$$

where $\hat{z}_t$, $\hat{y}_t$, $\hat{k}_t$ and $\hat{l}_t$ are the percentage deviations from the deterministic trend. Given the parameter θ chosen above and empirical series for $\hat{y}_t$, $\hat{k}_t$ and $\hat{l}_t$, we construct the series for $\hat{z}_t$ residually.

The procedure to construct the series of credit variable ξ_t is not standard but it is based on the same idea. Under the assumption that the enforcement constraint is always satisfied with equality, we have that:

$$\xi_t \overline{V}_t(k_{t+1}, b_{t+1}) = y_t$$

Of course, the assumption that the enforcement constraint is always satisfied with equality needs to be verified ex-post which we will do later.

The idea is to use this equation to construct the sequence of ξ_t over the period 1984-2008. This requires empirical series for $\overline{V}_t(k_{t+1}, b_{t+1})$ and y_t. While GDP is the natural empirical counterpart of output y_t, choosing the empirical counterpart of $\overline{V}_t(k_{t+1}, b_{t+1})$ is a more challenging task. In principle we could use stock market variables. Unfortunately, the empirical series for the stock market are so noisy that are difficult to reconcile with the values predicted by the model. More specifically, while in the model $\overline{V}_t(k_{t+1}, b_{t+1})$ tracks quite closely the book value of equity $k_{t+1} - b_{t+1}/R_t$, this is not the case in the data. Therefore, we take a different approach.

Our approach is based on the recognition that in the model $\overline{V}_t(k_{t+1}, b_{t+1})$ tracks very closely the book value of equity $k_{t+1} - b_{t+1}/R_t$. In fact, given the linearity of the production function, the book value of equities at the end of the period should not be very different from its dynamic value. In the special case in which $\tau = 0$ and $\kappa = 0$, $\overline{V}_t(k_{t+1}, b_{t+1})$ is exactly equal to $k_{t+1} - b_{t+1}/R_t$. As we will show later, when $\kappa > 0$, the value of the firm is not exactly equal to the book value of equities. However, the differences are not large. Therefore, we approximate $\overline{V}_t(k_{t+1}, b_{t+1})$ with $k_{t+1} - b_{t+1}/R_t$.

With this approximation the enforcement constraint can be written as:

$$\xi_t \left(k_{t+1} - \frac{b_{t+1}}{R_t} \right) = y_t$$

Taking a linear approximation and re-arranging we get:

$$\hat{\xi}_t = \hat{y}_t - \left(\frac{\bar{\xi}\bar{k}}{\bar{y}} \right) \hat{k}_{t+1} + \left(\frac{\bar{\xi}\bar{b}}{\bar{y}} \right) \hat{b}_{t+1}$$

where $\bar{\xi}$, $\bar{y}$, $\bar{k}$, $\bar{b}$ are steady state values (provided by the parameterized version of the model) and $\hat{\xi}_t$, $\hat{y}_t$, $\hat{k}_{t+1}$, $\hat{b}_{t+1}$ are percentage deviations from the steady state. Notice that, to simplify the notation, we have denoted by $\bar{b}$ and $\hat{b}_{t+1}$ the steady state and percentage deviation of the end of period debt b_{t+1}/R_t.

To compute $\hat{\xi}_t$ we need empirical sequences for $\hat{y}_t$, $\hat{k}_{t+1}$ and $\hat{b}_{t+1}$. To build these sequences, we first construct real series for capital, debt and value added in the nonfinancial business sector. The log of these variables are then detrended linearly. The detrended series are the empirical counterparts of $\hat{k}_t$, $\hat{b}_t$ and $\hat{y}_t$. A more detailed description of how we construct these series is provided in the appendix. The top panel of Figure 2 plots the time series for the productivity and credit variables, $\hat{z}_t$ and $\hat{\xi}$.

Once we have constructed the time series for the productivity and credit variables, we estimate the two dimensional system:

$$\begin{pmatrix} \hat{z}_{t+1} \\ \hat{\xi}_{t+1} \end{pmatrix} = A \begin{pmatrix} \hat{z}_t \\ \hat{\xi}_t \end{pmatrix} + \begin{pmatrix} \epsilon_{t+1} \\ \varepsilon_{t+1} \end{pmatrix}$$

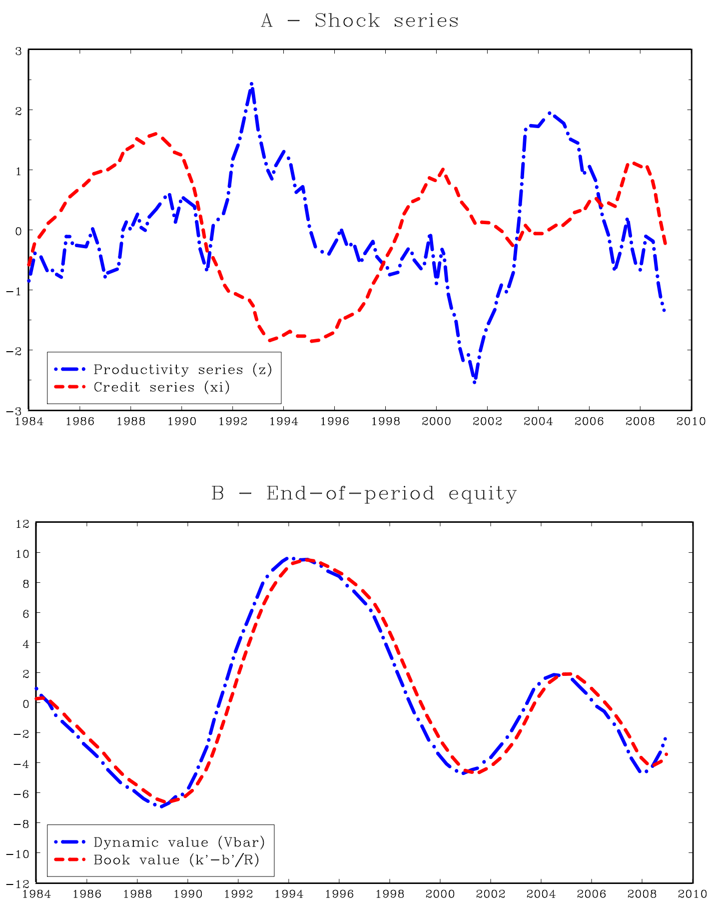

Figure 2: Panel A: Productivity and credit shocks series normalized by the corresponding standard deviations. Panel B: Value of equities.

At this point we are left with the equity cost parameter κ. This is chosen so that the standard deviation of equity payout over the period 1984:1-2009:1 is as in the data. The full set of parameters values are reported in Table 2. The numerical procedure is described in Appendix D and the impulse responses to a one-time shock (productivity and credit) are reported in Appendix E.

Before proceeding, we show that the variable $\overline{V}_t(k_{t+1}, b_{t+1})$ does in fact tracks closely the book value of equities $k_{t+1} - b_{t+1}/R_t$. These two variables are plotted in the bottom panel of Figure 2. This insures that the approximation adopted to construct the credit variable is sufficiently accurate.

Table 2: Parametrization.

Description	
Discount factor	$\beta = 0.9825$
Tax advantage	$\tau = 0.3500$
Utility parameter	$\alpha = 1.8893$
Production technology	$\theta = 0.3600$
Depreciation rate	$\delta = 0.0250$
Enforcement parameter	$\bar{\xi} = 0.1752$
Payout cost parameter	$\kappa = 0.2150$
Matrix for the shocks process	$A = \begin{bmatrix} 0.895 & -0.007 \\ -0.171 & 0.974 \end{bmatrix}$

4.2 Findings

We conduct the following exercise. Starting with the initial values $\hat{z}_{1984:1}$ and $\hat{\xi}_{1984:1}$, we use the estimated parameters of the autoregressive structure linking these two variables to generate the sequence of innovations ϵ_t and ε_t that replicates exactly the series $\hat{z}_t$ and $\hat{\xi}_t$, for $t = 1984 : 2, .., 2009 : 1$. We then feed these innovations or shocks into the model and compute the responses for the key macroeconomic and financial variables. Notice that, although we feed into the model the actual shocks, they are not perfectly anticipated by agents. They forecast future values of z_t and ξ_t using the autoregressive system specified above. To study the importance of the two shocks with and without financial frictions, we first show the responses of the model without frictions ($\tau = 0$ and $\kappa = 0$). We will then show the responses with financial frictions ($\tau > 0$ and $\kappa > 0$).

4.2.1 Model without financial frictions

Figure 3 plots the responses of financial flows, output and labor for the model without financial frictions. This is obtained by setting $\tau = 0$ and $\kappa = 0$. For the real sector of the economy the model becomes equivalent to the standard RBC model.

As can be seen from the figure, the simulated series are quite different

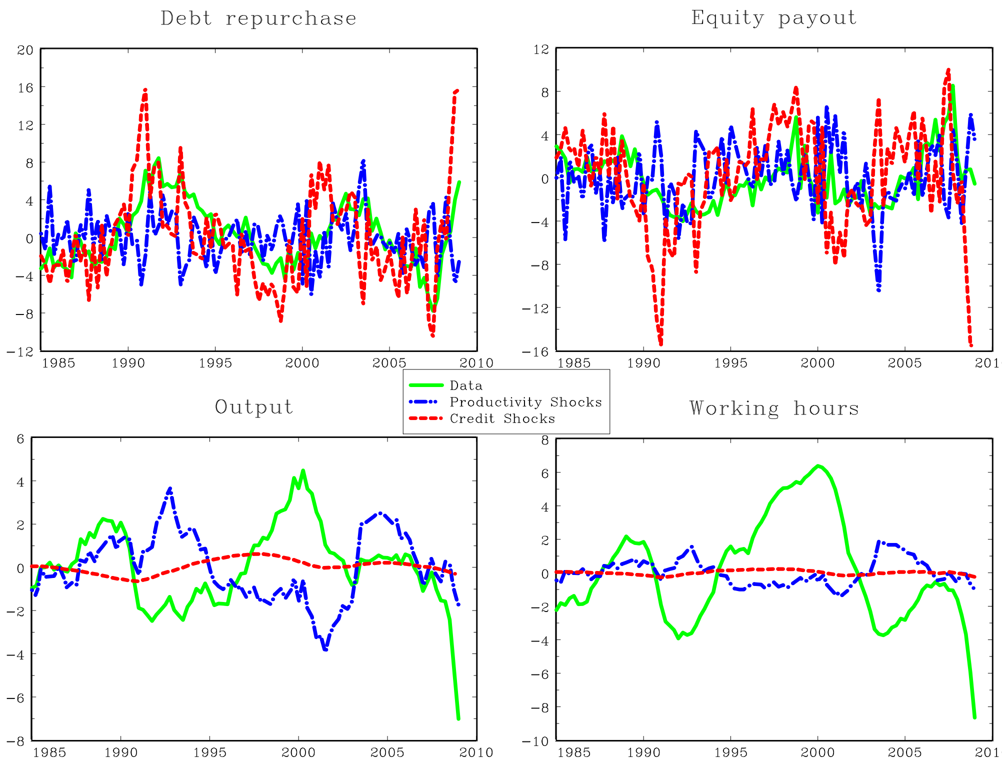

Figure 3: The dynamics of financial and real variables without financial frictions.

from the data. The productivity series induces a path for output that is significantly different from the data. In particular, while the data shows an output boom during the 1990s, the simulated series displays a decline. It is also worth emphasizing that the model does not generate the large output drop observed during the last two quarters of 2008 and the first quarter of 2009. Also, the drops in output experienced by the US economy during the previous two recessions are significantly smaller than in the data.

The performance of the model in terms of labor is even worse. Now the model is also unable to generate enough volatility of hours. In the sensitivity analysis we will show that this finding is robust to the alternative specification of preferences based on indivisible labor as in Hansen (1985). Notice that credit shocks are not completely neutral, which seems to contradict Proposition 3.2. This derives from the fact that credit shocks are correlated with productivity shocks. Thus, a change in ξ induces a change in productivity. The increase in z, however, is relatively small. If we impose independence between the two shocks, the responses of output and labor to credit shocks will be flat.

4.2.2 Model with financial frictions

Now we consider the model with credit frictions ($\tau = 0.35$ and $\kappa = 0.215$). Figure 4 plots, separately, the responses to productivity and credit shocks. The responses to productivity shocks are generated by feeding the model with the actual sequence of z_t and setting ξ_t to the unconditional mean. Similarly, the responses to credit shocks are generated by feeding into the model with actual sequence of ξ_t and setting to z_t to the unconditional mean.

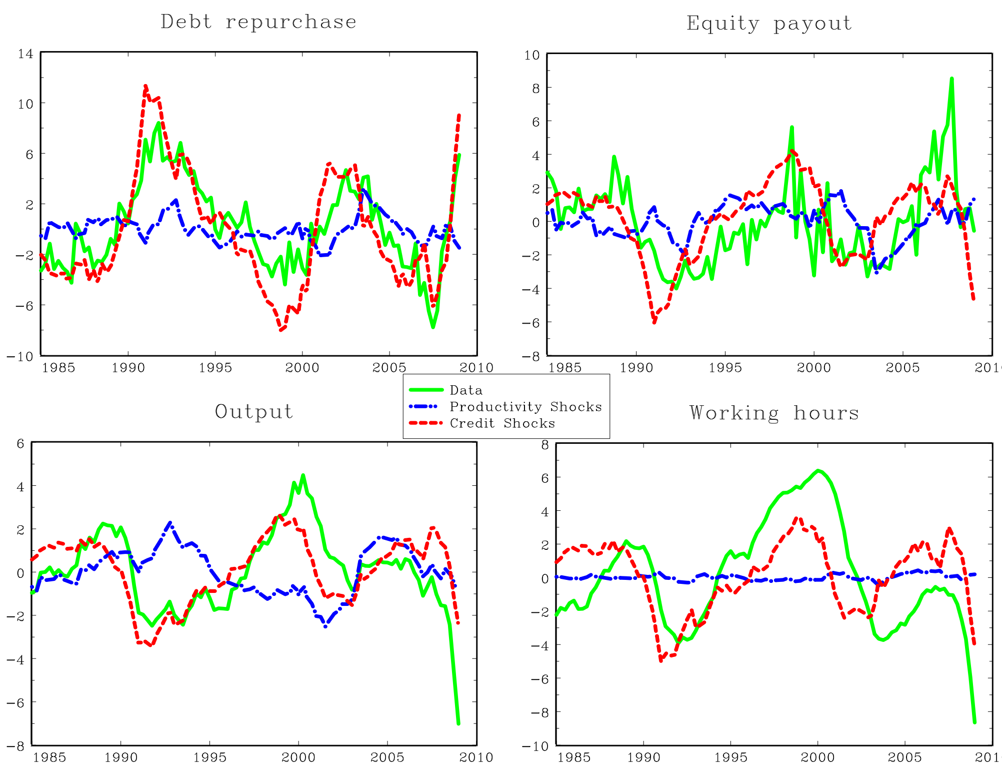

Figure 4: The dynamics of financial and real variables with financial frictions.

The responses to productivity shocks are very similar to those generated by the frictionless model, although the amplitude declines somewhat. This is because, for the particular parametrization, financial frictions dampens the response to productivity shocks. In fact, from the enforcement constraint $\overline{V}_t \geq F(z_t, k_t, l_t)$ we can see that the increase in productivity and consequent increase in output make the enforcement constraint tighter. As a result, the demand for labor increases less than in the frictionless economy.

Let's look now at the responses to credit shocks. The output and labor dynamics generated by credit shocks is much closer to the data. In particular we now see a boom in output and hours during the 1990s. Furthermore, credit shocks generate sharp drops in output and labor in all three major recessions: 1990-91, 2001 and 2008-09.

The improved performance of the model relies on the direct impact that credit shocks have on the demand for labor. As shown in the last panel of Figure 4, credit shocks generate much larger fluctuations in working hours. More importantly, it generates large drops in labor during the three recessions, as well as an upward trend during the 1990s.

The importance of the credit shocks for the demand of labor can be seen from the first order condition (3), which for convenience we rewrite here:

$$F_l(z, k, l) = w \cdot \left(\frac{1}{1 - \mu\varphi_d(d)}\right)$$

The variable μ is the multiplier for the enforcement constraint. A negative credit shock makes the enforcement constraint tighter, increasing the multiplier μ and the wedge on the cost of labor. This effect becomes bigger if the change in equity payout is costly (in which case $\varphi_d(d) \neq 1$). Intuitively, if the firm wants to keep the same production scale and hire the same number of workers, it has to reduce the equity payout. Because this is costly, the firm chooses in part to reduce the equity payout and in part to reduce the input of labor.

It will also be instructive to see the dynamics of the lagrange multiplier μ which captures the degree of financial tightness. As shown in Figure 5, the financial tightness increases drastically in all major recessions. Also notice that, for the simulated period, the multiplier remains always positive (since it never falls by more than 100 percent from its steady state value). This confirms that, at least in the linearized model, the enforcement constraint is always binding for the particular sequence of shocks considered in the simulation. Of course, this does not insure that in the 'non-linearized' model the enforcement constraint is necessarily always binding. However, the fact that the multiplier never becomes negative is an indicator that our assumption of a binding constraint is not a bad approximation. We have also solved the model non-linearly using parameterized expectations, which allows for non-binding constraints. The results are very similar to those obtained with the linearized model.

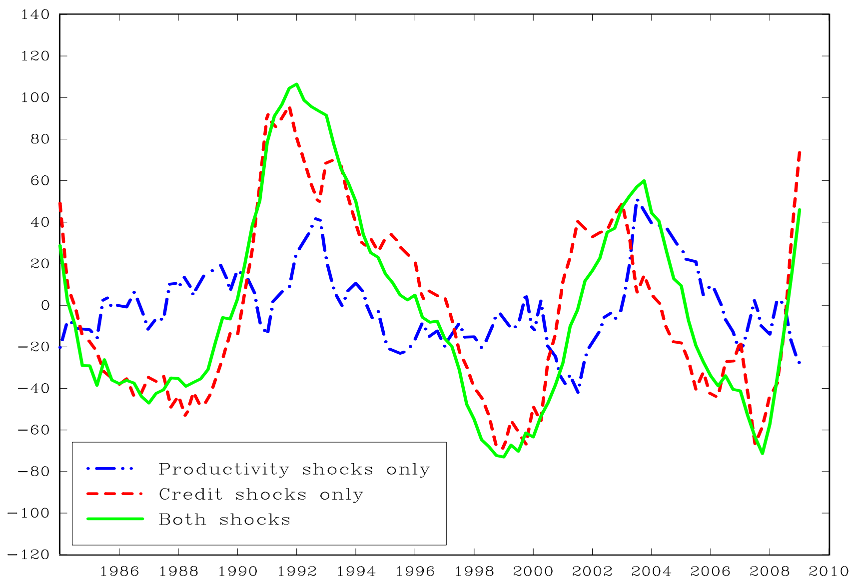

Figure 5: Financial tightness. Percent deviation of multiplier from its steady state value.

Figure 6 plots the impulse responses when both shocks are feeded into the model. For financial flows and labor, the performance of the model is very similar to the case with only credit shocks. In fact, the movements of these variables are mostly driven by credit shocks. For output, the performance is not as good as in the case with only credit shocks but certainly better than in the case with only productivity shocks. Still, we see that the model predicts sharp drops in output in each of the three major recessions experienced during the sample period.

5 Sensitivity analysis

The results shown so far are based on a particular value of κ. This parameter was chosen to replicate the standard deviation of the financial flows.

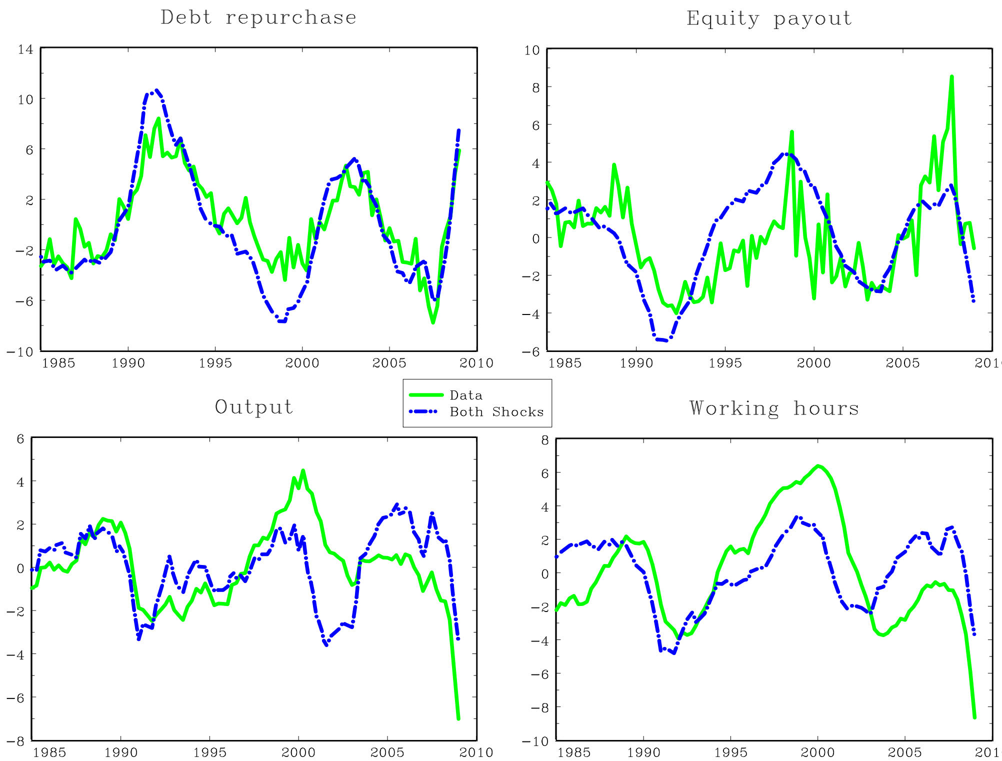

Figure 6: The dynamics of financial and real variables with financial frictions.

We now investigate the sensitivity of our results to κ. Figure 7 plots the responses of financial flows, output and labor for different values of κ. In constructing these responses we feed into the model the same series of z_t and ξ_t used in the construction of the previous graphs. Lower values of κ reduce the responses of real variables but increase the responses of financial flows. However, even if we reduce to one tenth the value of κ, credit shocks still contribute significantly to the fluctuation of output and labor.

The last sensitivity analysis we conduct is with respect to the specification of the disutility of labor. Since Hansen (1985), it has become common in business cycle studies to use a linear specification of the disutility of labor. We now show that our results are robust to this alternative specification of the utility function.

We repeat the same experiment described in the previous section but using the utility function $\log(c_t) - \alpha h_t$. The only parameters that change are

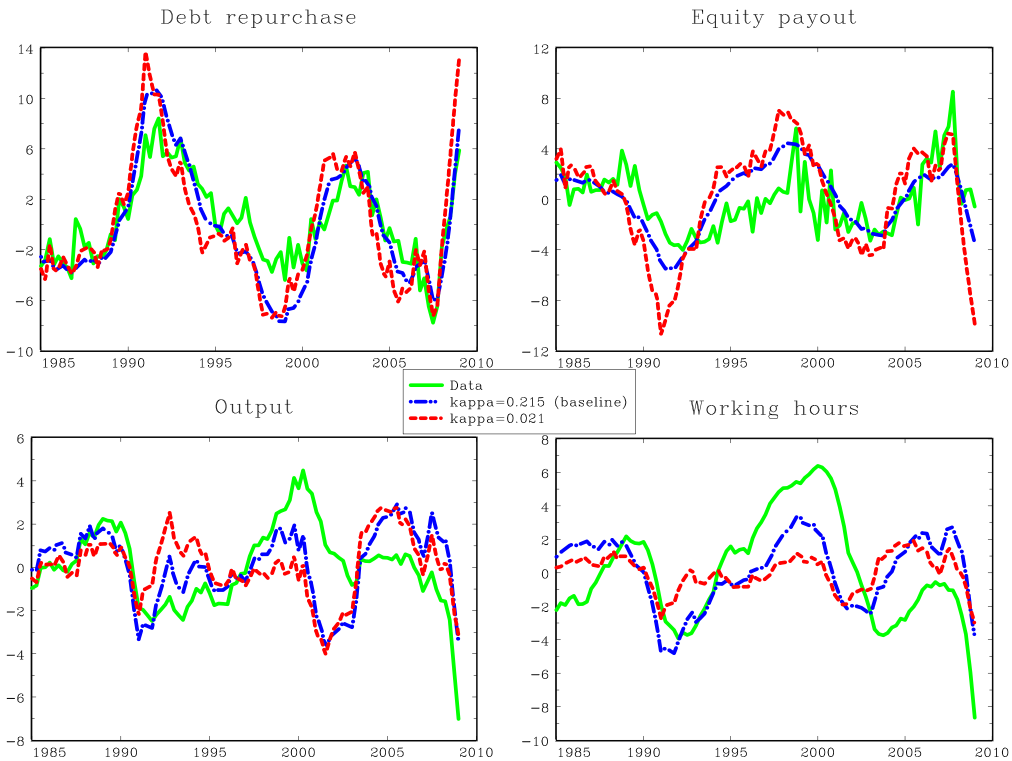

Figure 7: The dynamics of financial and real variables with financial frictions. Sensitivity to κ.

α and κ. Given the different specification of the utility function, we need a different value of α in order to have that agents spend an average of 30 percent of their time working. The parameter κ also needs to be changed in order to target the sum of the empirical volatility of equity payout. The change in κ is however very small: from 0.215 to 0.207. The simulation results are shown in Figure 8.

6 Conclusion

Are financial frictions and shocks that affect directly the financial sector important for macroeconomic fluctuations? The analysis of this paper suggests that they are. Models driven solely by productivity shocks have a number of known shortcomings in replicating key macroeconomic variables. We propose

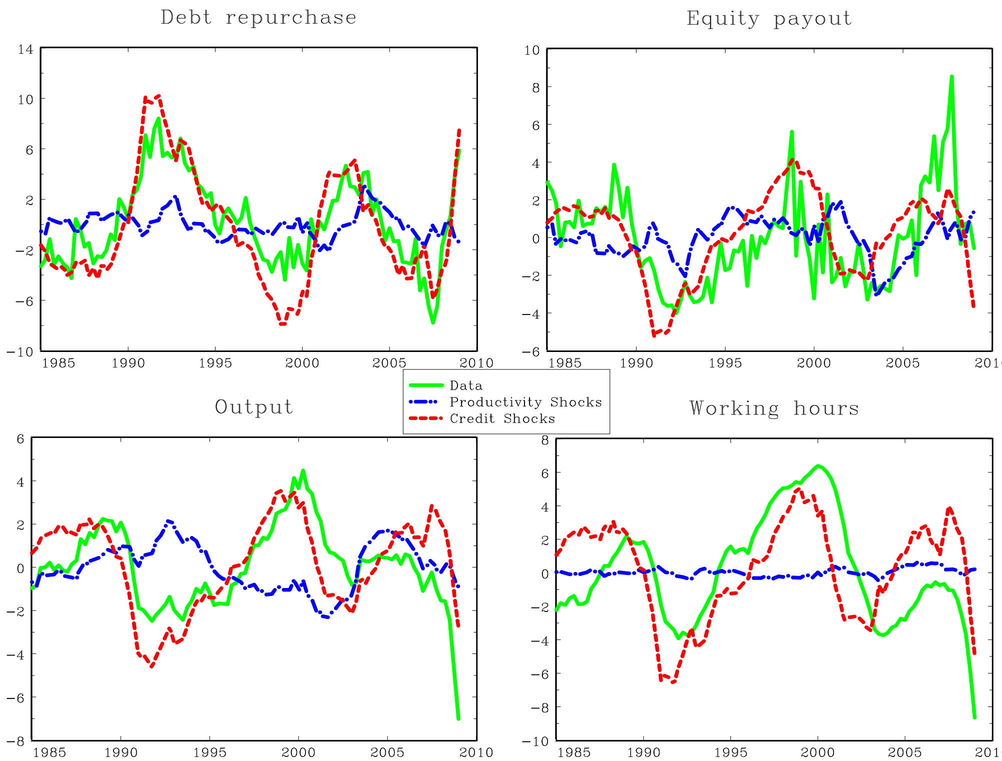

Figure 8: The dynamics of financial and real variables with financial frictions. Sensitivity to utility of leisure.

a model that incorporates explicitly the flows of debt and equity. Within this model we show that shocks to firms' ability to borrow, combined with some rigidities to change their financial structure, can bring the model closer to the data. This is possible thanks to the impact that credit shocks have on the demand of labor.

When we use the model to interpret recent economic events, the following picture emerges. The recent financial crisis shows up clearly in our model as a tightening of firms' financing conditions leading to a sharp downturn in labor and GDP growth during the last two quarters of 2008 and the first quarter of 2009. Tight financial conditions have also been important in the previous macroeconomic downturns of 1990-91 and 2001.

Appendix

A Data sources

Financial data is from the Flow of Funds Accounts compiled by the Federal Reserve Board. Outstanding debt is 'Credit Market Instruments' of Nonfarm Nonfinancial Corporate Business (B.102, line 22) and Nonfarm Noncorporate Business (B.103, line 24). This includes mainly Corporate Bonds (for the corporate part), mortgages and bank loans (for corporate and noncorporate); it doesn't include trade and tax payables. Debt Repurchases are defined as the negative of 'Net Increases in Liabilities' for 'Credit Market Instruments' for the Nonfinancial Corporate Business (F.102, line 39) and for the Noncorporate Business (F103, line 22). Equity Payout in the Nonfinancial Corporate Business is 'Net Dividends' (F.102, line 3) minus 'Net New Equity Issue' (F.102, line 38). Equity Payout in the Noncorporate Sector is the negative of 'Proprietors' Net Investment' (F103, line 29). Total assets and liabilities are as reported by the Flow of Funds in the Nonfinancial Corporate Business (B.102, line 1 and 21) and in the Noncorporate Business (B.103, line 1 and 23). All macro variables are from the Bureau of Economic Analysis (BEA).

B Derivation of the enforcement constraint

Firms start the period with liabilities b_t. Before producing they choose the labor input, l_t, investment, $i_t = k_{t+1} - (1-\delta)k_t$, dividends, $\tilde{d}_t$, and the next period debt, b_{t+1}. The tilde over the dividend will become clear later in the main text of the paper. The payments of wages, investments, dividends and previous debt is made before the realization of revenues. In order to make these payments the firm contracts an intra-period loan to cover the cash flow mismatch during the period. The intra-period loan is equal to $b^i_t = w_t l_t + i_t + \tilde{d}_t + b_t - b_{t+1}/R_t$. The intra-period loan is fully repaid at the end of the period after the realization of revenues. Because it is repaid within the period, there are no interests. Given the budget constraint $b_t + w_t l_t + i_t + \tilde{d}_t = F(z_t, k_t, l_t) + b_{t+1}/R_t$, it can be verified that the intra-period loan is equal to the firm's revenues, that is, $\hat{b}_t = F(z_t, k_t, l_t)$.

The decision to default on the intra-period loan arises after the realization of revenues $F(z_t, k_t, l_t)$. Because the firm has the ability to divert these revenues, the intra-period lender can only access the residual equities of the firm. Suppose that the liquidation value of the firm is a fraction ψ_t of the residual equity, that is, $\psi_t \overline{V}_t$, where ψ_t is stochastic and depends on (unspecified) markets conditions.[4]

[4]This fraction can result from the assumption that the sale of the firm requires the search for a buyer with which the lender bargains the price. The fraction ψ_t can then

Notice that at the end of the period the intertemporal debt is not due until the next period. Therefore, it is only the residual equity of the firm (net of the intertemporal loan) that guarantees the intra-period loan.

Because $\psi_t < 1$, there is a loos of value in the liquidation of the firm. Therefore, both the lender and the firm have an interest in renegotiating the loan.

Bargaining is over the repayment of the intra-period debt. Denote by e_t the payment agreed upon by the contractual parties. By reaching an agrement, the firm make the payment e_t but continues operation. Therefore, the firm gets $F(z_t, k_t, l_t) - e_t + \overline{V}_t$ and the lender gets e_t. Without agreement, the firm gets the threat value $F(z_t, k_t, l_t)$ and the lender gets the liquidation value $\psi_t \overline{V}_t$. Therefore, the net value of reaching an agreement for the firm is $\overline{V}_t - e_t$ and for the lender is $e_t - \psi_t \overline{V}_t$.

Denote by η the bargaining power of the firm and $1 - \eta$ the bargaining power of the lender. The bargaining problem solves:

$$\max_{e_t} \left\{ (\overline{V}_t - e_t)^{\eta} (e_t - \psi_t \overline{V}_t)^{1-\eta} \right\}$$

Taking the first order conditions and solving we get $e_t = \overline{V}_t[1 - \eta(1 - \psi_t)]$.

Incentive-compatibility requires that the value of not defaulting, $\overline{V}_t$, is not smaller than the value of defaulting, $F(z_t, k_t, l_t) - e_t + \overline{V}_t$. Therefore, the enforcement constraint is $\overline{V}_t \geq F(z_t, k_t, l_t) - e_t + \overline{V}_t$. Using $e_t = \overline{V}_t[1 - \eta(1 - \psi_t)]$ derived above, the enforcement constraint can be written as:

$$\overline{V}_t \geq F(z_t, k_t, l_t) + \eta(1 - \psi_t)\overline{V}_t$$

Collecting terms and rearranging we get:

$$\xi_t \overline{V}_t \geq F(z_t, k_t, l_t),$$

where $\xi_t = 1 - \eta(1 - \psi_t)$.

If we assume that the bargaining power of the firm is $\eta = 1$, we have that ξ_t is the fraction recovered in the sale of the firm, that is, $\xi_t = \psi_t$. However, we will get so the same functional form for the enforcement constraint for any value of the bargaining power $\eta > 0$. Therefore, the assumption that $\eta = 1$ is without loss of generality.

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being interpreted as the probabilities of finding the buyer and/or the bargaining power of the lender in the determination of the selling price. The probability of finding a buyer and/or the price extracted in the bargaining process increase when the market conditions are good.

C First order conditions

Consider the optimization problem (2) and let λ and μ be the Lagrange multipliers associate with the two constraints. Taking derivatives we get:

$$\begin{aligned}
d: &\quad 1-\lambda\varphi_d(d)=0\\
l: &\quad \lambda F_l(z,k,l)-\lambda w-\mu F_l(z,k,l)=0\\
k': &\quad (1+\xi\mu)Em'V_k(\mathbf{s}';k',b')-\lambda=0\\
b': &\quad (1+\xi\mu)Em'V_b(\mathbf{s}';k',b')+\frac{\lambda}{R}=0
\end{aligned}$$

The envelope conditions are:

$$\begin{aligned}
V_k(\mathbf{s};k,b) &= \lambda\Big[1-\delta+F_k(z,k,l)\Big]-\mu F_k(z,k,l)\\
V_b(\mathbf{s};k,b) &= -\lambda
\end{aligned}$$

Using the first condition to eliminate λ and substituting the envelope conditions we get:

$$\begin{aligned}
&F_l(z,k,l)=w\left(\frac{1}{1-\mu\varphi_d(d)}\right)\\
&(1+\xi\mu)Em'\left(\frac{\varphi_d(d')}{\varphi_d(d)}\right)\Big[1-\delta+(1-\mu'\varphi_d(d'))F_k(z',k',l')\Big]=1\\
&(1+\xi\mu)R\,Em'\left(\frac{\varphi_d(d')}{\varphi_d(d)}\right)=1
\end{aligned}$$

Defining $\tilde{m}'=m'\varphi_d(d')/\varphi_d(d)$ and substituting we get (3)-(5).

D Numerical solution

We solve the model after log-linearizing the dynamic system around the steady state. The system of dynamic equations is as follows:

$$wU_c(c,l)+U_l(c,l)=0 \tag{9}$$

$$U_c(c,l)=\beta(1+r)EU_c(c',l') \tag{10}$$

$$wl+b-\frac{b'}{R}+d-c=0 \tag{11}$$

$$F_l(z,k,l) = w\left(\frac{1}{1-\mu\varphi_d(d)}\right) \tag{12}$$

$$(1+\xi\mu)E\,\tilde{m}(c,l,d,c'l',d')\Big[1-\delta+(1-\mu'\varphi_d(d'))F_k(z',k',l')\Big] = 1 \tag{13}$$

$$(1+\xi\mu)RE\,\tilde{m}(c,l,d,c',l',d') = 1 \tag{14}$$

$$F(z,k,l) - wl - b + \frac{b'}{R} - k' - \varphi(d) = 0 \tag{15}$$

$$\xi Em(c,l,c',l')V' = F(z,k,l) \tag{16}$$

$$V = d + Em(c,l,c',l')V' \tag{17}$$

Equations (9)-(11) are the first order conditions for households and their budget constraint. Equations (12)-(14) are the first order conditions for firms and (15)-(17) are the budget constraint, the enforcement constraint and the value function.

We have nine dynamic equations. After linearizing around the steady state, we can solve these equations for the variables c_t, d_t, l_t, w_t, R_t, V_t, μ_t, k_{t+1}, b_{t+1}, as linear functions of the states, z_t, ξ_t, k_t, b_t.

E Impulse responses to shocks

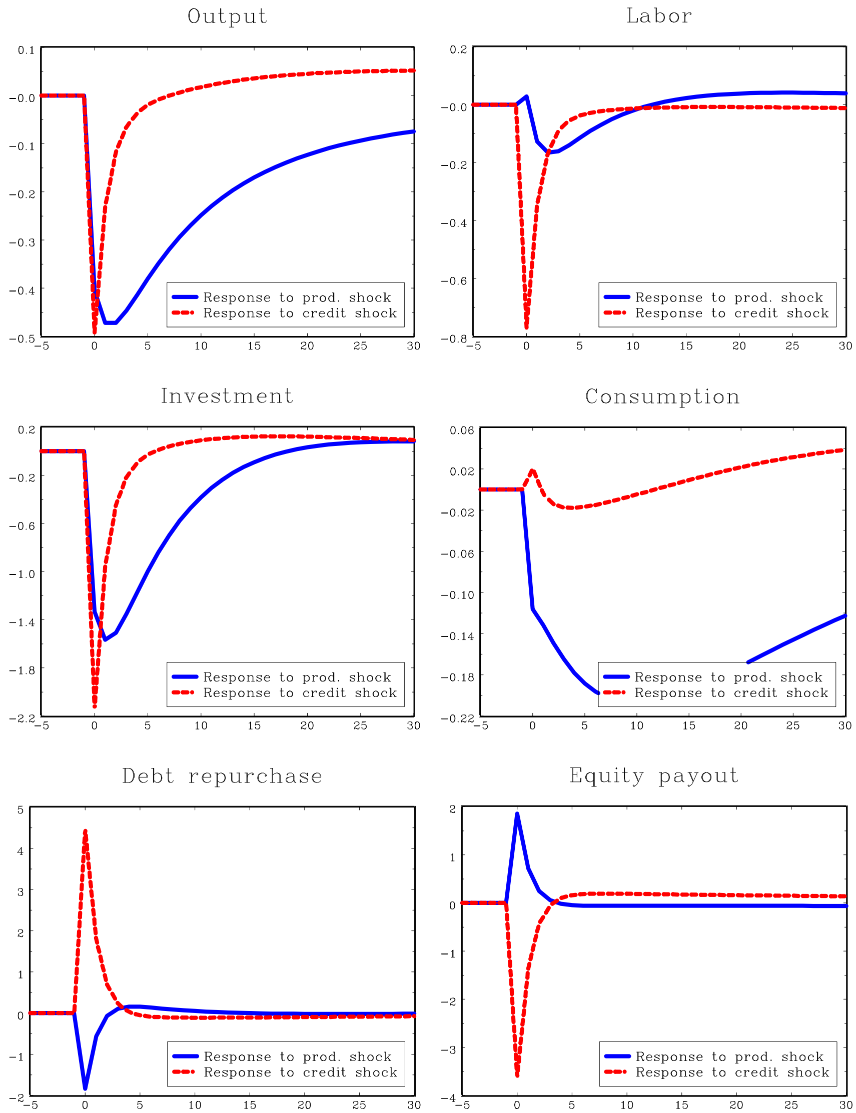

Figure 9: Impulse responses to a negative, one standard deviation innovation to productivity and credit variable. Economy with financial frictions ($\tau = 0.35$ and $\kappa = 0.215$).

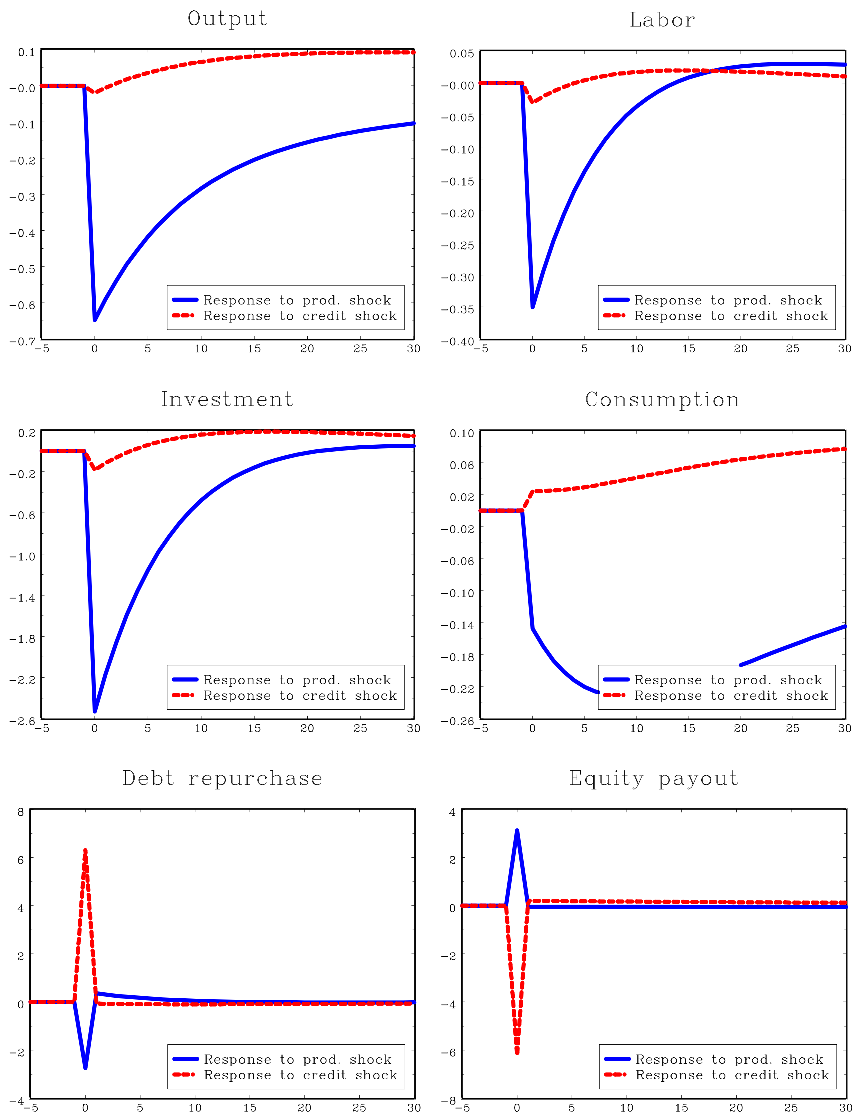

Figure 10: Impulse responses to a negative, one standard deviation innovation to productivity and credit variable. Economy without financial frictions ($\tau = 0$ and $\kappa = 0$).

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